Special Topics on Basic EECS I
VLSI Devices
Lecture 1

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Course

- Course number: EC4301
- 3 credits
- 09:00~10:15 on every Monday/Wednesday
- Instructor: Sung-Min Hong

Outline

- VLSI devices
  - Simply, MOSFET
- Purpose of this courses
  - Advanced course for MOSFETs
- Contents (See the syllabus.)
  - Electrons and holes in silicon
  - PN junctions
  - MOS capacitors
  - Metail-silicon contacts
  - High-field effects
  - …

Prerequiste and references

- Semiconductor Materials and Devices (EC3206)
- Textbook
  - Y. Taur and T. H. Ning, Fundamentals of Modern VLSI Devices

Prof. Yuan Taur
(UCSD)

Resources

- Presentation materials
  https://github.com/hi2ska2/device2024s

- Homework submission and notice
  - GIST LMS system

- YouTube channel
  https://www.youtube.com/@SungMinHong

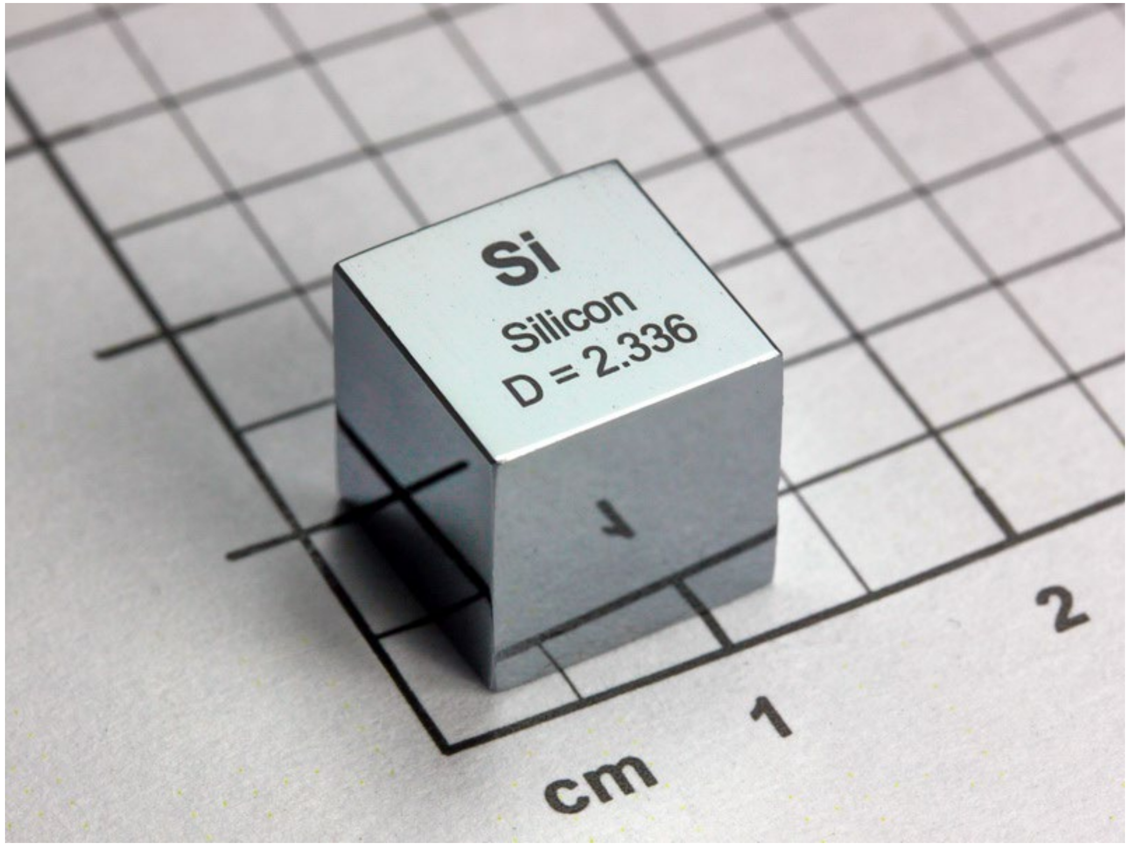
Grading and policy

- Attendance: 10 %
- Mid-term examination: 40 %
- Final examination: 50 %

- You have some homeworks.
  - However, it does not contribute to the total score.

Number of elelctrons in Si

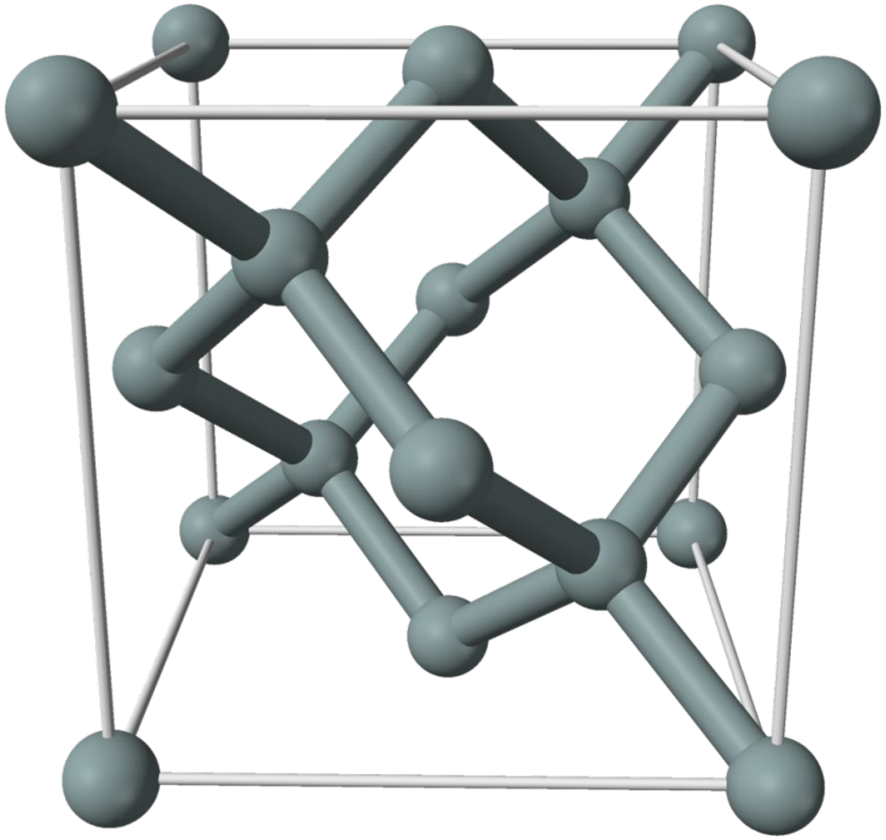
- ~ 5 X 10^{22} Si atoms in 1 cm^3
  - 14 electrons for each Si atom



Silicon cube
(Smart-elements.com)

Crystal structure of Si

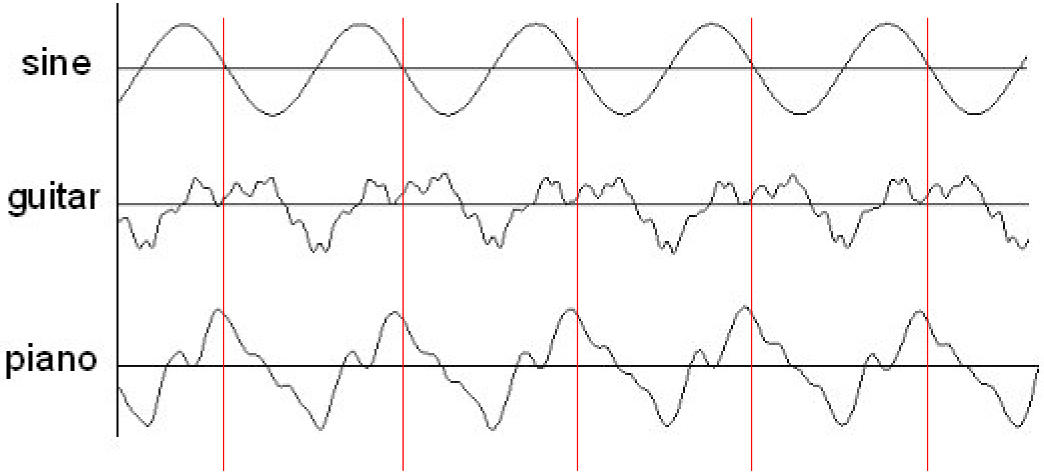
- Diamond structure
  - FCC (face-centered cubic) lattice + two-atom basis



Diamond structure
(Wikipedia)

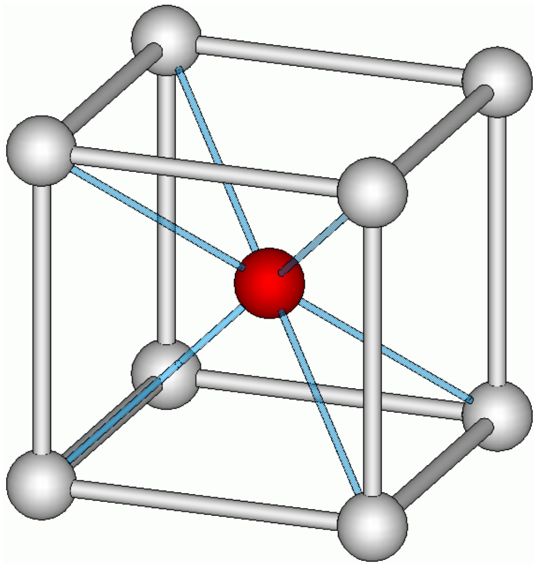
Lattice & basis

- Analogy to sound
  - FCC (face-centered cubic) lattice + two-atom basis



Waveforms (yuvalnov.org)

- 3D example
  - Cesium Chloride (CsCl)
  - Its lattice is the simple cubic. (Not BCC)



Crystal structure of CsCl (Wikipedia)

Basis vectors

- FCC
  - Basis vectors of the direct lattice

$$\mathbf{a}_1 = \frac{a}{2}\begin{bmatrix} 0 \\ 1 \\ 1 \end{bmatrix}, \mathbf{a}_2 = \frac{a}{2}\begin{bmatrix} 1 \\ 0 \\ 1 \end{bmatrix}, \mathbf{a}_3 = \frac{a}{2}\begin{bmatrix} 1 \\ 1 \\ 0 \end{bmatrix}$$

  - Basis vector of the reciprocal lattice

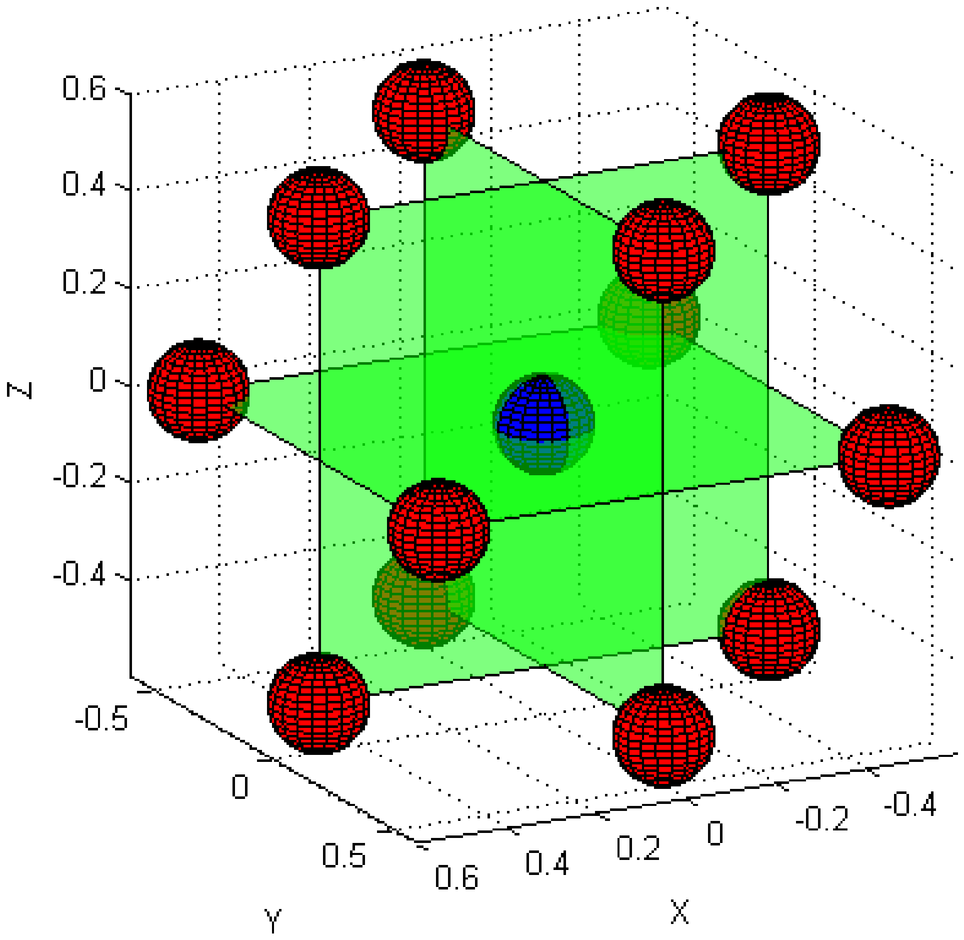
$$\mathbf{b}_1 = \frac{2\pi}{a}\begin{bmatrix} -1 \\ 1 \\ 1 \end{bmatrix}, \mathbf{b}_2 = \frac{2\pi}{a}\begin{bmatrix} 1 \\ -1 \\ 1 \end{bmatrix}, \mathbf{b}_3 = \frac{2\pi}{a}\begin{bmatrix} 1 \\ 1 \\ -1 \end{bmatrix}$$

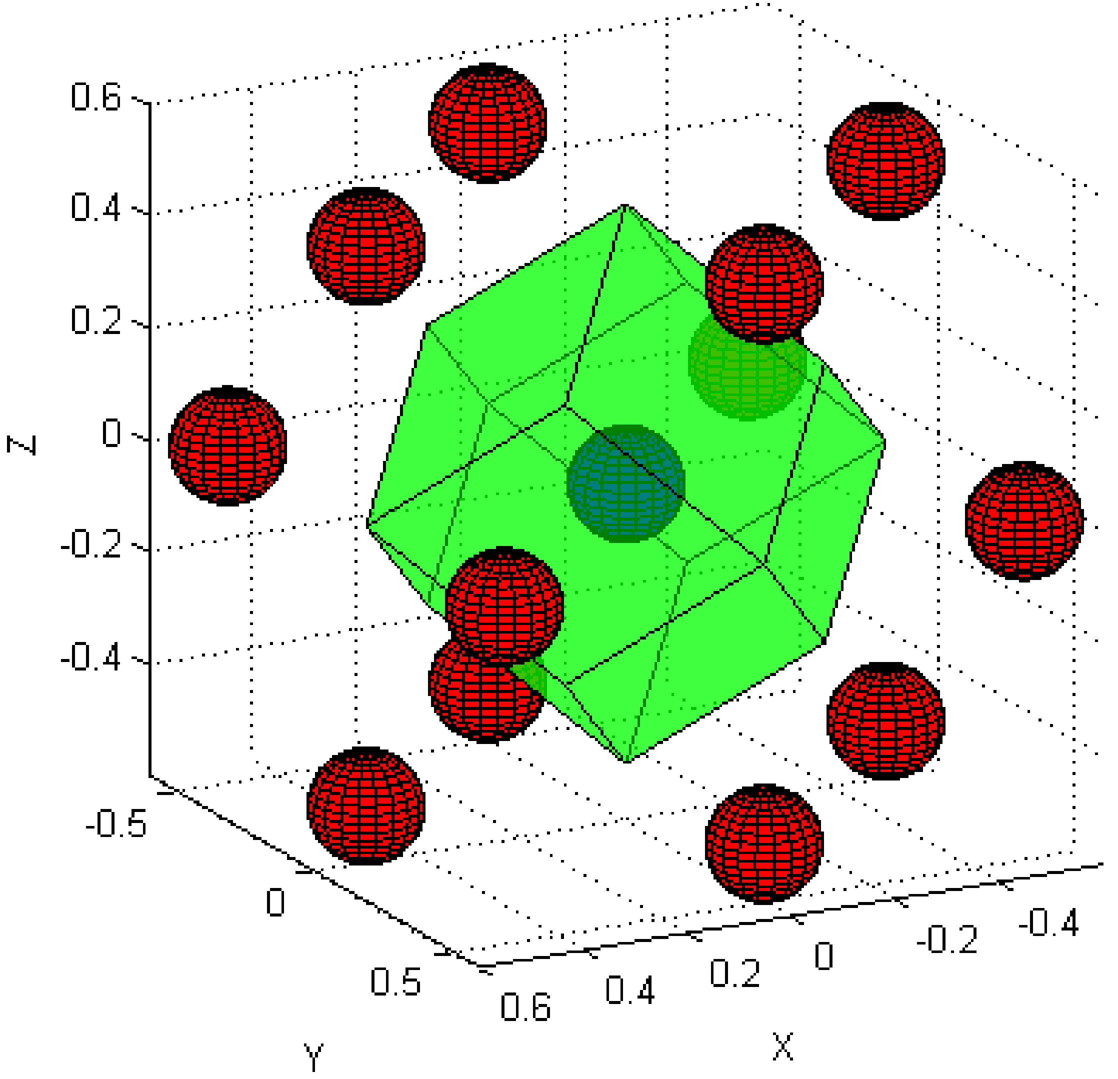
  - Relation between them:

$$\mathbf{a}_i \cdot \mathbf{b}_j = 2\pi\delta_{ij}$$

Wigner-Seitz primitive cell

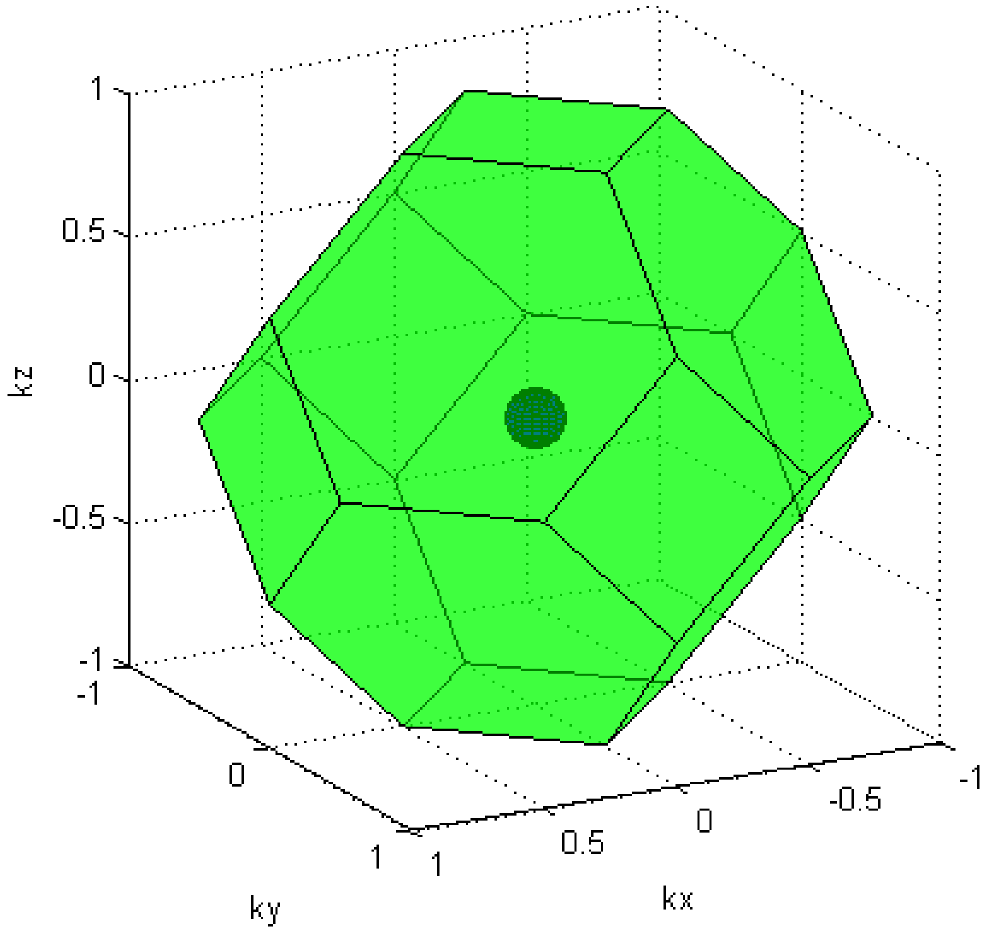
- Lattice points and Wigner-Seitz cell
  - Unit: a





Brillouin zone

- Wigner-Seitz cell of the reciprocal lattice
  - Unit: $\frac{2\pi}{a}$



Miller index and related notations

- For the special case of simple cubic crystals, the lattice vectors are orthogonal and of equal length (usually denoted a), as are those of the reciprocal lattice. Thus, in this common case, the Miller indices (hkl) and $[hkl]$ both simply denote normals/directions in Cartesian coordinates. (Wikipedia)
  - Plane: (hkl)
  - All equivalent planes: $\{hkl\}$
  - Direction: $[hkl]$
  - All equivalent directions: $< hkl >$

Thank you!